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ABSTRACT

The complex and multi-faceted nature of the cognitive process of reasoning is discussed. The factor-analytic history of the isolation and definition of the three most important currently recognized reasoning factors (general reasoning, induction, and logical or deductive reasoning) is traced through the psychometric literature, and the interdependence of these abilities is discussed. Examples of many test item-types which have been found to define these factors are presented with empirical documentation of their importance and use in a variety of test batteries and with different examinee populations. (Author/BW)

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The Definition and Measurement of Reasoning

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THE DEFINITION AND MEASUREMENT OF REASONING

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United States Civil Service Commission
Washington, D. C. 20415
August 1977

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ABSTRACT

The complex and multi-faceted nature of the cognitive process of reasoning is discussed in this report. The factor-analytic history of the isolation and definition of the three most important currently recognized reasoning factors (General Reasoning, Induction, and Logical or Deductive Reasoning) is traced through the psychometric literature and the interdependence of these abilities is discussed. Examples of many test item-types which have been found to define these factors are presented with empirical documentation of their importance and use in a great variety of test batteries and with different examinee populations.

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Introduction

Reasoning can be broadly defined as a logical thinking process which results in some decision or conclusion. Within the general context of "reasoning" there are the concepts of Induction (simplistically defined as reasoning from specific facts to general conclusions) and Deduction (the reverse process of drawing a specific conclusion from given general facts). A report on the analysis of the mathematical logic underlying Induction and Deduction and precise definitions of the two concepts is in preparation.

The present paper will trace the history of reasoning abilities (general or quantitative, inductive, deductive) as they have been identified and measured in many factor-analytic studies reported in the psychological literature. Although the concepts of Induction and Deduction are mathematically distinct, and indeed they have been measured as separate dimensions of reasoning throughout their psychometric history, it is only realistic to recognize that in the "real world" the two are inseparable - that any task of a problem-solving nature will necessarily require more than a single dimension of ability. Many types of situations call for reasoning behavior, e.g., expressing and applying a rule or principle to a relationship, solving a problem by "insight," formulating hypotheses to account for phenomena, making inferences, combining experiences or concepts into new and different relationships, detecting fallacies in the solution to a problem (Adkins and Lyerly, 1952). Needless to say, many kinds of tests have been used to assess these behaviors. Since it is true of factor-analytic methods that the number and kinds of tests in a test battery will influence, if not determine, the factors extracted, it is not surprising that studies aimed at isolating and identifying reasoning abilities (note the plural) have often presented conflicting results and interpretations. It is for this reason, i.e. the variety of measures associated with reasoning, that one study may produce a "General Reasoning" factor, another will isolate Deduction and/or Induction and a third will extract three or four factors possibly related to reasoning - none of them very clear.

It should be stressed here that factor analysis is a statistical tool for clustering a large number of variables into a few meaningful dimensions, or factors, and that this clustering is mathematically based upon the intercorrelations among these variables. The psychological interpretation (that is, the naming) of these factors is a subjective matter influenced by the point of view and objectives of the person who carried out the analysis. This latter is important because authors differ in their definitions of, and criteria for, "reasoning," the level at which they wish to explore it (as a general phenomenon or in its numerous specific aspects) and in the completeness of the analysis which they carry out. Inconclusive results can be due to an insufficient number and variety of reasoning-type tests or to a lack of good reference tests for ability factors with which reasoning can be confused and/or confounded. For example, any reasoning test in the verbal medium will possess some variance in the Verbal ability factor and tests which will isolate and identify this factor should be included in the battery. If this is done, the verbal components in the tests for reasoning can be separated from the true reasoning components.

With all of the foregoing in mind we can proceed to the documentation of the several reasoning abilities as measurable psychological constructs. The remainder of this report will cover research carried out with three major sources of cognitive tests-those developed by Thurstone with their subsequent revisions and adaptations, those developed by the Army Air Force Aviation Psychology Program during World War II and those developed in the laboratory of J. P. Guilford.

Thurstone and the Primary Mental Abilities

The first major study to identify and measure the dimensions of human cognitive ability was undertaken by Thurstone (1938a). From a factor analysis of 56 tests representing a wide variety of mental activities, Thurstone extracted nine primary mental ability factors. Among these were three factors considered to be in the realm of reasoning, two of them somewhat tentatively.

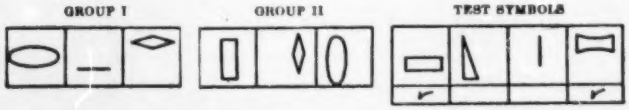
The clearest of the three factors was identified as Induction because the tests which had significant factor loadings on it had one common characteristic - they all demanded that the examinee find a rule or principle in order to solve each test item. Factor loadings for the prominent tests in this factor were as follows:

Figure Classification	.40
Areas	.48
Tabular Completion	.48
Number Series	.50
Pattern Analogies	.39

The following are examples from each of these tests.[1]

Figure Classification (originally used by Spearman as a good test of "G")

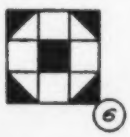
Find the rule by which Group I differs from Group II.
Check the test symbols which belong in Group I



In Group I the symbols are horizontal; in Group II they are vertical. The horizontal Test symbols have been checked.
(Thurstone, 1938a, p. 25)

Areas

Determine the total white area in terms of squares (use fractions where necessary).



answer: 6 (Thurstone, 1938a, p. 42)

Tabular Completion

In the following table there are blank spaces. Fill in the correct numbers in these spaces. Get the necessary information from the rest of the table. Use the space below each table and on the opposite page for figuring.

Year	Marriages		Divorces		
	Number	Increase over Preceding Year	Number	Increase over Preceding Year	Number Granted to Husbar
1894.....	566,161	12,512	37,568	100	12,5
1895.....	598,855	32,694	40,387	2,819	
1896.....	613,873	15,018	42,937		14,448
1897.....	622,350			1,762	14,765
Total..	2,401,239	No total	165,591	No total	55,22

(Thurstone, 1938a, p. 44)

Number Series

The numbers in each row follow one another according to some rule. Find the rule and fill in the blanks to fit the rule.

8 11 14 __ 20 __

(Thurstone, 1938 a, p. 44)

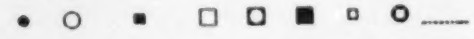
answer: 17, 23

[1] All item-type examples appear again in alphabetic order in the Appendix, for easy reference whenever these tests are mentioned again in the text.

Pattern Analogies

Find the rule by which Figure A is changed to Figure B. Apply the rule to Figure C.

A B C 1 2 3 4 5



answer: 1

(Thurstone, 1938a, p. 50)

The second and third factors previously referred to were regarded as residual factors by Thurstone with only tentative identifications. Factor R consisted of the following tests with their factor loadings:

Arithmetic Reasoning	.58
Numerical Judgment	.53
Completion	.48
Vocabulary (Thorndike)	.54
Vocabulary (Chicago)	.46

Thurstone did not give this factor a name but merely noted that the common characteristic among the tests seemed to be the "successful completion of a task that involves some form of restriction in the solution" and that "further study of arithmetical and other restrictive tasks will reveal the nature of this factor" (Thurstone, 1938a, p. 88). The following are examples of items from, or descriptions of, the above tests.

Arithmetic Reasoning

At 8 A.M. the barometric pressure was 30.6 and at 9 A.M. the pressure was 31.2. Assuming a constant rate of increase in barometric pressure, at what time was the pressure 31.0?

(item 5 from Arithmetic Reasoning Test. Supplement to Thurstone, 1938a)

Numerical Judgment

Check the correct answer to each problem 4.12395 x 6.82187 =

7.563327	_____
14.012468	_____
28.133051	✓
56.103378	_____

Correct answer checked

(Examinees are encouraged to estimate to find the answer, e.g. the first number is nearly 4, the second nearly 7 and 4x7=28)

(Thurstone, 1938a, p. 46)

Completion

There is one word missing in each of the following sentences. The first letter of the missing word is shown in the parentheses.

A short sleep or doze is a ...(n) nap

(Thurstone, 1938a, p. 28)

Vocabulary (Thorndike) - word knowledge

(Thurstone, 1938a, p. 57)

Vocabulary (Chicago) - 100 objective items, more difficult than Thorndike (Thurstone, 1938a, p. 57).

The presence of the two vocabulary tests in this factor is comprehensible in view of the "restriction in the solution" aspect of the tests which identify it. Zimmerman (1953) further rotated Thurstone's original primary mental ability factors and arrived at new factor loadings for the tests in the Restrictive Reasoning factor as follows:

Arithmetic Reasoning	.64
Numerical Judgment	.60
Completion	--
Vocabulary (Thorndike)	.36
Vocabulary (Chicago)	-.03

The revised rotation eliminated a large residual (or unaccounted for) variance in the original study and produced a more clear cut picture of the Reasoning factor, which Zimmerman now called General Reasoning.

The last of the three factors was labeled D by Thurstone. The tests with significant factor loadings are as follows:

Figure Classification	.40
Reasoning	.52
False Premises	.58

These tests are deductive in nature (Figure Classification involves the application of the rule after it has been found) but the list of tests is not long enough to justify

positive identification of the factor as Deduction. The following are examples of the Reasoning and False Premises items (Figure Classification has already been illustrated).

Reasoning (Syllogistic)

The examinee is to indicate after each statement whether the reasoning therein is good (+) or bad (-), i.e., does the conclusion follow logically from the premises. Since all metals are elements, the most rare of all metals must be the most rare of all elements. _____
answer: - (Thrustone, 1938a, p. 48)

False Premises (Nonsense syllogisms)

The instructions are the same as those for the Reasoning items.

All haystacks are catfish. All catfish are typewriters. Therefore all haystacks are typewriters. _____
answer: + (Thurstone, 1938a, pg. 49)

Immediately following his landmark monograph outlining the primary mental abilities, Thurstone (1938b) published a further study which sought to isolate the same factors using a different battery of tests and a different population of examinees. This time only one factor associated with reasoning ability emerged. It was defined as Induction, but with no certainty. The tests which most prominently identified this factor had been scattered among the three "reasoning" factors in the previous study. They were (with their current factor loadings):

Arithmetic Reasoning	.48
Tabular Completion	.44
Reasoning	.36

These tests also had moderate loadings on other factors, notably Verbal (all three) and Number (Arithmetic Reasoning).

Isolation of primary mental abilities continued (Thurstone, 1940) with the addition of new tests (e.g., Letter Series - similar to Number Series) and refinements of established tests (e.g., Reasoning II - complex syllogisms for which the response to the given conclusion was "yes," "no," or "can't tell" and Reasoning III - complex syllogisms for which the examinee was to choose the correct conclusion from five alternatives). The syllogistic tests had factor loadings of .27 to .38 on the Deduction factor (the original Restrictive Reasoning factor or R) and loadings of a similar magnitude on the Verbal factor. Arithmetic Reasoning shared its variance with Deduction (loading=.49) and the Number factor (.38). An Induction factor was identified by the following tests and factor loadings:

Letter Series	.39
Letter Grouping	.36
Marks	.43
Number Patterns	.36

The following are examples of items from these newer tests of Induction:

Letter Series

Find the next letter in the series:
c a d a e a f a _____
answer: g (Thurstone & Thurstone 1941, p. 65)

Letter Grouping

Mark the group that does not belong
AABC ACAD ACFH AACG
answer: underlined
(Thurstone & Thurstone, 1941, p. 64).

Marks (original not available - item is from Ekstrom, French and Harman, 1976, p. 82, an adaptation of Thurstone's Marks test).

The examinee is to mark one of five numbered places in a row of groups of dashes according to a rule.

```
Row 1  ------------- --x -----
Row 2  ----- --x-- ------------
Row 3  ------------- --x ------
Row 4  ----- --x---- ----------
Row 5  -------1-- --X--3-4 5---
```

The correct answer is "2" (in Row 5). In the first four rows the "x" always replaces the third dash from the left of a group. The group is always the second group in the row. The number "2" replaces the third dash of the second group in Row 5.

Number Patterns

In this test the examinee is presented with matrices of numbers and is to find a missing number according to a rule which relates all of the numbers.

What is the number that is left out?

1	5	9	4	A)	1
2		1	5	B)	6
3	7	2	6	C)	4
4	8	3	7	D)	5
				E)	3

The correct answer is "B." The numbers are in consecutive order going down the first column then down the second column, etc. The blank space should contain a 6.

(Thurstone and Thurstone, 1941, p. 67)

In still a further important study (Thurstone and Thurstone, 1941) a comprehensive battery of 60 cognitive tests produced one Reasoning Factor - identified as Induction because tests such as Letter Series, Letter Grouping and Number Patterns appeared on it with moderate loadings (.50, .37, and .26 respectively). A Deduction factor did not appear, due undoubtedly to the fact that only one test of a syllogistic (or deductive) nature was included in the battery. Items were of the type:

M is larger than O
O is larger than T
Therefore T is _____than M.

answer: smaller

(Thurstone & Thurstone, 1941, p. 75)

The highest loading for this test was .26 on the Number factor.

Investigations continued in order to clarify the identity of the several reasoning factors which have thus far been discussed. The many tests employed to isolate them had thus far been somewhat inconsistent in their attraction to a targeted factor (e.g., Induction or Deduction). It should be recalled that the number and kinds of tests in the entire test battery influence the factors which will be defined mathematically. So far, none of the Reasoning tests have had very high (i.e., .60 or above) loadings on any factor, indicating that they are somewhat complex and measure more than a single ability. This means that in any given test battery, if there are not a sufficient number of tests to measure, for example, deductive ability, the one or two which are included will appear in factors which account for other portions of their variance (e.g., verbal or number or "general reasoning") and a factor which can be specifically identified as Deduction will not be extracted. It has already been observed that the reasoning process is many-faceted and that most problem solving activities involve both inductive and deductive thinking as well as other elements such as "insight," "originality." or "fluency of ideas."

Thurstone's tests, or modifications and adaptations of them, were used in many further studies which, examined together, give a picture of the empirical documentation of the categories of reasoning over several decades. Table 1 presents a summary of some of these findings as well as those already discussed. Tests which identified one or more reasoning factors somewhat consistently are listed. Individual studies are found as column headings and the body of the table indicates which factor (Induction, Deduction, etc.) each test loaded on and the factor loading it achieved. All of the tests were not used in every study, of course, as is evident from the many blanks in the table.

Examination of Table 1 indicates that relationships among the reasoning factors as well as their positive identification were reported to be clearer in some studies than in others. Thurstone (1940) thought that D (Deduction) and R (Restrictive Reasoning) might be the same, whereas Thurstone and Thurstone (1941) and Goodman (1943) question the separateness of R and I (Induction). Rimoldi's (1951) observation that the solutions called for in many tests involve a dynamic system requiring both analysis and synthesis is lent credence by the association of tests like Figure Classification with Induction in some studies and Deduction in others. One discovers the rule or principle governing the figures (induction) and applies it to draw a conclusion about the correct answer (deduction).

TABLE 1

Empirical Documentation of Reasoning Factors (for Reasoning Tests in 13 Factor-Analytic Studies)

TEST NAME	Thurstone 1938a	Thurstone 1938b	Thurstone 1940	Thurstone & Thurstone 1941	Coombs 1941	Goodman 1943	Taylor 1947	Fruchter 1948	Botzum 1951	French 1957	Wrigley etal. 1958	Dunham & Bunderson 1969	Hakstian & Cattell 1974
Arithmetic Reas.	R?, .58 I, .33	I, .48			D, .57	R, .52 I, .34		R, .53	I, .31	GR,.32			
False Premises (Nonsense Syll.)	D?, .58								D, .42		D, .58	LR, .86	
Figure Classif.	D?, .40 I , .40								D, .42		I, .48 D, .12		
Letter Grouping (Letter Sets)			I, .36	I, .37	I, .22	I, .48	R,.47		I, .38	I, .29		I, .78	I,.77,.89
Letter Series			I,.39	I,.49 I(R?),.53		I,.49 I(R?).53	R,.49		I,.47				I,.43
Marks (Locations)			I,.43		D,.29 I,.30	I,.50				I,.30		GR.29 I,.66 LR,.36	
Number Patterns			I,.36		D,.25 I,.26	I,.41							
Number Series	I,.50		D(R?),.47 I,.26		D,.56	R.59 I,.18			I,.45		I,.45		
Reasoning	D?,.52	I,.36	D(R?).27, .38,.36								D,.53	I,.68	
Tab. Completion	I,.48	I,.44							I,.27		I,.29		

Factor Identifications

I = Induction
D = Deduction
R = Restrictive Reasoning
GR = General Reasoning
LR = Logical Reasoning (Deduction)

Army Air Force Research

During World War II the Army Air Force Aviation Psychology Program developed a large number of cognitive tests to be used for the selection and classification of air crew personnel. Numerous factor-analytic studies with a great variety of test batteries were carried out and much valuable information relative to cognitive ability factors was accumulated (Guilford and Lacey, 1947). One of these test batteries was composed of reasoning tests and included measures in the verbal, numerical and non-verbal non-numerical mediums. The following are samples of items from a representative number of these tests.

Arithmetic Reasoning (CI206C)

If a plane is to fly 132 miles in 45 minutes, what must be its average speed?

A. 146.7 m.p.h.
B. 164
C. 165
D. 176
E. 182

(Guilford and Lacey, 1947, p. 90).

Number Series

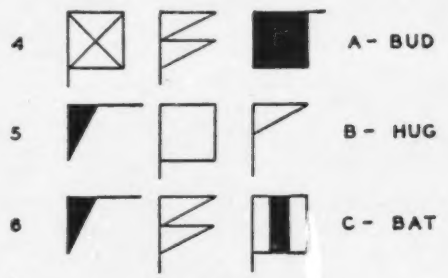
4 6 _____ 10 12 _____
(1) (2)

A 4	A 10
B 5	B 14
C 8	C 15
D 12	D 16
E 20	E 18

(Guilford and Lacey, 1947, p. 95).

Decoding-The test requires the decoding of short words written in a code of signal flags. The items are arranged in groups. In each group three to six rows of individual flag symbols are presented. Each symbol represents an unknown letter of the alphabet. They are arranged three or four to the row, and each row forms a commonplace English word when decoded. After examining the position of repeated flag symbols, it is possible to deduce the word that must correspond to each of the symbol lines. To illustrate the type of problem in the test, sample problem II, used in the directions, is shown. The accompanying text follows:

> Note that the letter b appears twice, each time at the beginning of a word. Since the symbol which appears at the beginning of two code words is a black pennant * * * this pennant must represent b. The letter u also occurs twice in these words, both times in the middle of a word. Thus the code symbol for u is the double white pennant * * * Since the first 2 symbols of item 6 are those which stand for b and u, this item must be bud. The other two items are solved by noting that item 5 begins with b and is therefore bat and that item 4 contains u as a middle letter and, therefore, must be hug * * *

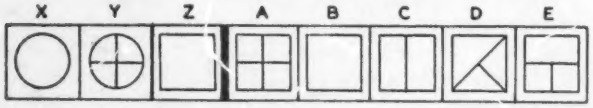


(Guilford and Lacey, 1947, p. 100)

Figure Analogies

Your task is to find which one of the five choices at the right goes with figure Z the same way figure Y goes with figure X. Figure X is a circle; figure Y is a similar circle divided into 4 equal parts. The figure that goes with figure Z the same way the divided circle Y, goes with the empty circle, X, is figure A. Of the five choices, figure A is

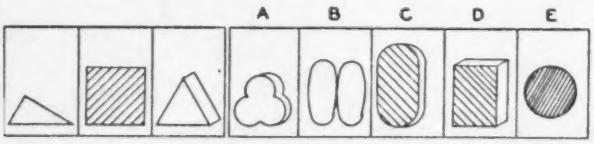
the only one which is divided into four equal parts. So, we can say figure X is to figure Y as figure Z is to figure A. Fill in A after number 1 on your answer sheet.



(Guilford and Lacey, 1947, p. 105)

Figure Classification

Select from the five alternatives the geometric figure that has the characteristic common to each of the three figures that set the problem.



The three figures to the left of the heavy line, although of different shapes and sizes, are alike in one way. The lines which bound the figure are straight lines. Now examine the five figures labeled A, B, C, D, and E. Find the one figure which is bounded only by straight lines. The only figure which meets this requirement is Figure D.

(Guilford and Lacey, 1947, p. 107)

Spatial Reasoning (a revision of Thurstone's Marks)

The test requires the examinee to detect the principle governing the placement of letter symbols in a spatial pattern of dashes and gaps.

The rule for example 2 is, "The number of marks to the left of X increases by one in each row. Y is just to the right of the last gap in each row. X and Y are omitted from the last row, but according to the rule, X should be at the 5th mark (E) and Y should be at the mark following the last gap (I). Blacken spaces E and I after item 2 on your answer sheet.

(Guilford and Lacey, 1947, p. 111)

Tests of Reading Comprehension and Vocabulary were also included in the Reasoning Test Battery in order to isolate the Verbal factor and identify the verbal variance contained in any of the reasoning tests. Similarly, a test of simple numerical operations (addition, subtraction, multiplication and division) was included to identify variance in the Number factor.

Table 2 presents a summary of relevant factor loadings from this analysis. Factor loadings of less than .20 have been omitted from the table.

The Numerical (N) and Verbal (V) factors were clearly marked by their reference tests as shown by the first two columns in Table 2. Not surprisingly, Number Series and Arithmetic Reasoning had large loadings (.47 and .51) on the Number factor and the latter test also appeared in the Verbal factor with a factor loading of .34. The factor represented by the third column in Table 2 has been called Reasoning I. All of the reasoning tests except Figure Classification had loadings on it, as did Reading Comprehension also. This factor was thought to be a General Reasoning factor-perhaps an all-purpose "trouble shooting" trait (Adkins and Lyerly, 1952).

Reasoning II (column 4) was only tentatively defined as a reasoning factor having to do with seeing relationships. None of its factor loadings were high and the tests associated with it were considered complex. Its existence as a true reasoning factor was dubious.

Reasoning III was another imprecisely defined factor. All of the reasoning tests except Number Series had loadings on this factor, none of them very high, however. It was tentatively associated with reasoning of a sequential nature (frequently the correct answer could be arrived at by eliminating wrong ones) or of hypothesis evaluation rather than formulation.

TABLE 2

Factor Analysis of Army Air Force Reasoning Tests

TESTS	FACTORS N	V	Reas. I	Reas. II	Reas. III	Int. III
Technical Vocabulary		.66				
Reading Comprehension		.65	.33	.27		
Numerical Operations	.69					
Arithmetic Reasoning	.51	.34	.55			
Spatial Reasoning			.46		.38	.38
Figure Classification					.32	.38
Figure Analogies	.20		.35	.40	.31	.28
Decoding			.36	.30	.37	
Number Series	.47		.36			.20

Factor loadings <.02 have been omitted.

TABLE 3

Factor Analysis of Army Air Force Judgment Tests

TESTS	FACTORS Verbal	Reas. I	Reas. II	Judgment
General Vocabulary	.52			
Commonsense Judgment	.26	.23		.32
Logical Reasoning Judgment	.28	.41		.27
Deductive Reasoning	.33			
Arithmetic Reasoning	.42	.40		
Syllogisms	.42		.20	
Figure Analogies	.38	.34	.51	

Factor loadings <.02 have been omitted.

No conclusive insight into reasoning tests was gained by this study. General Reasoning (Reasoning 1) has been encountered before (see Table 1) in factor analytic studies carried out with tests developed by and adapted from Thurstone. Arithmetic Reasoning tests seem to best characterize this factor. Note that Induction and Deduction are absent as factors. A likely explanation stems from the fact that numerous tests which had previously identified these factors (e.g., Letter Series and Letter Grouping for Induction; Syllogistic Reasoning for Deduction) were not present in the Reasoning Battery. Had tests of an inductive or deductive nature been present in sufficient numbers these factors may have emerged as they have in other studies.

A factor analytic study to investigate the factorial components of judgment added information which helped to clarify and establish Reasoning I as a true General Reasoning factor. The test battery consisted of a number of "judgment" tests (in which a predicament of some sort was presented and the examinee was to choose the best solution based upon practical, commonsense or logical principles). General Vocabulary, Arithmetic Reasoning, Figure Analogies and two new tests, deductive in nature, were included. The following are examples of items from these two tests.

Deductive Reasoning

"This test is designed to measure ability to draw a logical conclusion from a problem situation."
(Guilford and Lacey, 1947, p. 144).

An inspector general has an appointment in a city one hundred miles away. If the train on which he must travel is late, he will miss his appointment. If the train is not late, he will miss the train. We do not know whether the train is late. With this information, we can state positively that

A. He will not be able to keep his appointment.
B. He will be able to keep his appointment.
C. There is no way of telling whether he will be able to keep his appointment.
D. He will have to take a later train.
E. He will have to wait for the train.

Syllogisms

"This [test] is intended to measure logical reasoning ability unaffected by habitual modes of thought."
(Guilford and Lacey, 1947, p. 146).

Only thieves hide jewels. This man hid jewels. Therefore he must be a thief.

If the last sentence is a necessary conclusion, mark answer space A. If the last sentence is not a necessary conclusion, mark answer space B.

Table 3 presents factor loadings for relevant tests and factors in this study. All of the tests listed had substantial loadings on the Verbal factor, not surprising since all except Figure Analogies are in the verbal medium. The instructions for Figure Analogies, however, are verbal and this probably accounts for its association with the Verbal factor. General Reasoning (Reasoning I) was again identified by the Arithmetic Reasoning and Figure Analogies tests as well as by two of the Judgment tests. A factor loading of .19 on Reasoning I for the Deductive Reasoning test is not entered in Table 3, since only loadings of .20 or greater were considered. However, in a parallel study of the same test battery, using high school students rather than aviation trainees, Deductive Reasoning had a factor loading of .35 on the General Reasoning factor. Reasoning II still did not receive a definite identification.

Many of the Air Force reasoning tests were used in subsequent explorations of cognitive ability dimensions in general and the realm of reasoning in particular. Arithmetic Reasoning continued to be indicative of General Reasoning (French, 1951; Guilford, Fruchter and Zimmerman, 1952; Michael 1949; Zachert and Friedman, 1953) as did Figure Classification (Guilford, Fruchter and Zimmerman, 1952; Roff, 1952). None of these studies employed a sufficient number of reasoning tests to enable more than one reasoning factor to appear; therefore no clarification, or even demonstration of the existence of, more specific reasoning components (e.g., induction or deduction) was presented.

Studies by Guilford and Others

An extensive investigation of factors associated with Reasoning was undertaken by Adkins and Lyerly (1952) using a battery of 66 tests. Included in the battery were a large variety of reasoning tests including many developed by or adapted from Thurstone, and some of those used by the Army Air Force in its Classification Batteries. Reference tests for other well established factors (e.g., Reading Comprehension paragraphs and Vocabulary for the Verbal factor; simple Numerical Operations for the Number factor) were also present in the test battery. In some cases two or three variations of the same test were used; for example, there were three Figure Classification tests among the 66 variables: the first was that used by the Army Air Force, an example of which appears earlier in this report and in the Appendix. The other two were adapted from Thurstone's tests using two and three groups of test symbols (an example of the former can be found in the Appendix).

Sixteen factors were extracted, including the expected Verbal and Numerical factors. As broad a concept as General Reasoning did not emerge - the Arithmetic Reasoning test shared variance with a Concept Formation factor (loading =.29), the Numerical factor (.33) and an unnamed Residual (.28). This test, however, was unlike other arithmetic reasoning tests. The problems were very simple, verbally, and actual working of the problem was not required but only an understanding of the method or principle involved. The following is an example:

Necessary Arithmetic Operations

John had a dollar. He spent 80¢. To find out how much John had left, it is necessary to:

_____ add
__X__ subtract
_____ multiply
_____ divide

(Adkins & Lyerly, 1952, p. 22)

Necessary Arithmetic Operations has appeared in several other studies on a General Reasoning Factor. Kettner, Guilford and Christensen (1956) reported a factor loading of .49, Lemke, Klausmeier and Harris (1967) a factor loading of .87, and Dunham and Bunderson (1969) a factor loading of .90.

A factor identified as Deduction was characterized chiefly by Thurstone's test False Premises (an example is given in the Appendix) with a factor loading of .45. A Verbal Analogies test also had a moderate loading on this factor (.26). Items in this measure were of the following type:

> Choose from among the alternatives the word which bears the same relation to the third word in the stem as the second word does to the first.
>
> SKY-BLUE: GRASS-
> A. earth
> B. green
> C. path
> D. blue
>
> answer: B (Adkins & Lyerly, 1952, p. 52)

A factor which could definitely be called Induction was not isolated; instead three factors of an inductive nature were present. They were Hypothesis Verification (emphasis on the testing of hypotheses), Perception of Abstract Similarities (emphasis on perception and the formulation of hypotheses) and Concept Formation (the ability to generalize). Table 4 presents a summary of factor loadings on the Deduction and three Inductive factors for a number of frequently used reasoning tests or variations of them. The appearance of Verbal Analogies in the Reasoning factors and its absence in the Verbal factor is interesting. Thurstone did not find this test associated with reasoning, but it had the second highest loading (.60) of any of his tests on the Verbal Comprehension factor. The Number and Verbal factors and the factor Flexibility of Perceptual Closure (the structuring of a visual field in various ways with the ability to shake off distracting material) are also included, because a

TABLE 4

Factor Loadings of Selected Tests on Reasoning, Numerical and Verbal Factors*

	De-duction	Hypoth. Verif.	Perc. Abst. Sim.	Concept Form.	Flex. of Closure	N	V
Arithmetic[1]				.29		.33	
Circles[2]	.20				.26	.31	
Conclusions[3]			.26				
Decoding[4]			.25	.23	.26		.20
False Premises[5]	.45	.30					
Figure Classif. I[6]			.29		.14		
Figure Classif. II[7]					.50		
Figure Classif. III[8]		.26			.44		
Letter Series[9]				.26		.30	
Verbal Analogies[10]	.26	.32	.21	.33			

1. From AAF - Necessary Arithmetic Operations
2. Adaptation of Thurstone's Marks
3. Thurstone's Reasoning Test
4. AAF
5. Thurstone
6. AAF
7. Thurstone - 2 Group
8. Thurstone - 3 Group
9. Thurstone
10. Variety of sources

*Constructed from information in Adkins and Lyerly (1952).

number of tests relevant to Reasoning are strongly associated with them. Pemberton (1952) investigated the relationship between Closure factors and other cognitive processes. Using Letter Series, Number Series and Figure Classification as "classic" tests of Induction, Pemberton found that these three tests appeared in both Reasoning and Closure factors, with loadings ranging from .43 to .56, and hypothesized that closure was really inductive thinking.

The Flexibility of Perceptual Closure factor has been conceived by Ross (1977) as being related to Perceptually Based Induction, as opposed to Verbally Based Induction assessed by tests such as Letter Series.

The great preponderance of reasoning tests in Adkins and Lyerly's investigation led to the extraction of many specific factors which are all possible aspects of reasoning. There appears to be nothing in their work which refutes the many previous factor-analytic studies already discussed. If anything, they have confirmed the complexity of reasoning behavior, have demonstrated yet again that reasoning tests are not factor-pure measures and that any problem-solving activity must involve a combination of such reasoning processes as induction and deduction.

During the next two decades (1950-1970) a whole host of investigations in a number of cognitive areas (e.g., reasoning, evaluation, creative thinking, planning) were undertaken by Guilford and his colleagues. Michael, Zimmerman and Guilford (1951) isolated the Verbal, Numerical, Spatial, Visual, Perceptual Speed and General Reasoning factors from a test battery. Again, the General Reasoning factor was characterized by tests of Arithmetic Reasoning and by Thurstone's Reasoning test (Syllogisms), with factor loadings of .58 and .51 respectively for a sample of male high school students and .61 and .58 for a sample of females.

Subsequently, in Guilford's laboratory, attempts were made to resolve questions relative to the three Reasoning factors tentatively identified by the Army Air Force research project (Green, Guilford, Christensen, and Comrey, 1953; Guilford, Christensen, Kettner, Green and Hertzka, 1954). Four Reasoning factors were hypothesized:

Reasoning I - the ability to define and solve problems, organize steps, test hypotheses; in other words, a general thinking factor analogous to the Air Force Reasoning I .

Reasoning II - the ability to see rules, principles, trends, relations. (AAF Reasoning II).

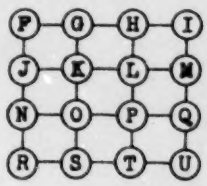
Reasoning III - classifying ability, seeing common elements (AAF Reasoning III).

Reasoning IV - Thurstone's Deduction.

The results of these studies indicated that Reasoning I was indeed a General Reasoning factor, identified by Arithmetic Reasoning and a new measure developed in Guilford's laboratory called Ship Destination. The following is an example of an item from this test.

Ship Destination.

Find the distances from ships to ports, taking into account an increasing number of variables. The distance between neighboring positions is 2 miles.



Sample variables: 1. Ship N to Port O 2. Ship J to Port G

Answers. 1 - 2 miles; 2 - 4 miles

(Guilford and Hoepfner, 1971, p. 473)

Factor loadings for Arithmetic Reasoning were .43 and .41 in these two studies; for Ship Destination they were .33 and .39.

Reasoning II and Reasoning III were redefined as possible dimensions of Inductive thinking. A figure classification test had a factor loading of .32 on a factor called Eduction of Conceptual Relations which was similar to Adkins and Lyerly's Perception of Abstract Similarities, one of three factors with inductive properties.

Reasoning IV was far easier to identify with deductive thinking and was renamed Logical Reasoning. The tests with the highest loadings on this factor were those associated with the logical rules of deduction:

Syllogisms	.47
Inference	.47

The Inference test was a new one developed in Guilford's laboratory. The following is an example of one of its items:

Inference Test.

Choose one of five conclusions that follows from a factual, meaningful premise.

Sample premise: Most of the trees in the forest are green.

Alternative conclusions:

A) There are no yellow trees in the forest.
B) There are some yellow trees in the forest.
C) Some of the trees in the forest are green.
D) Green trees are the tallest in the forest.
E) Pine trees are green.

Answer: C
(Guilford and Hoepfner, 1971, p. 414)

Green et al. (1953) pointed out that reasoning tests do not always transcend the medium (e.g., verbal, numerical) in which they are constructed. The Arithmetic Reasoning test still had factor loadings of around .40 on the Numerical factor and Inference had Verbal loadings of .30 to .50. Precise definitions of reasoning were still controversial. General Reasoning was conceptualized as a broad pervasive ability, present in many tests. Reading Comprehension, Syllogistic tests of deduction, and inductive tests such as Figure Classification all had moderate (around .30) loadings on General Reasoning. In addition, marker tests for General Reasoning such as Arithmetic Reasoning and Ship Destination also appeared in the Logical Reasoning and Inductive factors. The difficulty encountered in separating induction and deduction is discussed by Guilford et al. (1954). These authors hypothesized that although induction and deduction are concepts from formal logic, they are not necessarily applicable to a human function or ability. Logical reasoning, for example, involves a sensitivity to logical rules and their orderly application to the testing of the correctness of a conclusion, but not an explicit awareness of rules as taught in a course in logic. Furthermore, items in a multiple choice format do not require an examinee to produce a conclusion but only to perform an act of evaluation when deciding which of the given conclusions is correct.

Further investigations in a variety of cognitive areas, e.g., evaluative abilities (Hertzka, Guilford, Christensen and Berger, 1954), creative thinking (Wilson, Guilford, Christensen and Lewis, 1954), general reasoning (Kettner, Guilford and Christensen, 1956), planning (Berger, Guilford and Christensen, 1957), flexibility in thinking (Frick, Guilford, Christensen and Merrifield, 1959), the combined domains of reasoning, creativity and evaluation (Kettner, Guilford and Christensen, 1959) and problem solving (Merrifield, Guilford, Christensen and Frick, 1962) have provided gradual clarification of reasoning abilities. Further studies are cited in Guilford and Hoepfner (1971). Since these studies present such a variation in numbers and kinds of tests which have made up the different test batteries, populations used (high level military personnel, college students, high school students) and have emphasized different specific areas of cognitive ability rather than overall general ability as did Thurstone's investigations, no attempt will be made to report and compare numerical factor loadings. Suffice it to say that the results of many investigations have converged and at present three aspects of reasoning are recognized as important and measurable ability constructs. They are:

General Reasoning - "the ability to solve a broad range of reasoning problems including those of a mathematical nature." (French, Ekstrom and Price, 1963, p. 33).

This definition has been revised by Ekstrom, French and Harman (1976, p. 133) to read: "the ability to select and organize relevant information for the solution of a problem."

Syllogistic Reasoning (originally Deduction) - "The ability to reason from stated premises to their necessary conclusions." (French, Ekstrom and Price, 1963, p. 37).

The factor name and definition have been revised by Ekstrom, French and Harman, 1976, p. 141 to read -

Logical Reasoning (originally Deduction) - "The ability to reason from premise to conclusion, or to evaluate the correctness of a conclusion."

Induction - "Associated abilities involved in the finding of general concepts that will fit sets of data, the forming and trying out of hypotheses." (French, Ekstrom and Price, 1963, p. 19).

The definition has been revised by Ekstrom, French and Harman, 1976, p. 79 to read - "This factor identifies the kinds of reasoning abilities involved in forming and trying out hypotheses that will fit a set of data."

Table 5 presents a rough summary of the reasoning tests which have been most consistently associated with the three reasoning factors, according to studies cited in this section. The absence of association of these tests with General Reasoning, Logical Reasoning (Deduction) or Induction in some of the studies is indicative of two things - a) the test was not used in the particular study and/or b) the Reasoning factor with which it was expected to be allied was not one of the factors extracted in the study and the test went to other factors.

Examination of Table 5 reveals that nine of the eleven tests listed have had loadings on more than one of the Reasoning factors. Ekstrom, French and Harman (1976, p. 133) state that "some researchers have had problems in separating general reasoning from logical reasoning." Entries for Arithmetic Reasoning, Ship Destination and Syllogistic tests (both of the formal and nonsense variety) corroborate this observation. In addition these authors (p. 79) point out that "both Cattell and Pawlik have concluded that induction and general reasoning are probably not separate factors." Cattell (Hakistian and Cattell, 1974) prefers to think of the General Reasoning factor not as a primary mental ability but as an incomplete manifestation of the higher order Fluid Intelligence function" (p. 148). Table 5 indicates that four of the tests (Figure Classification, Letter Series, Locations and Necessary Arithmetic Operations) have all been associated with both Induction and/or General reasoning. Lastly, there is some evidence for the possible inseparability, in an empirical sense, of Induction and Deduction. Both Verbal Analogies and Nonsense Syllogisms have appeared in both factors in a single study.

In spite of some controversy regarding the separateness of the three reasoning abilities, they are still assessed as separate cognitive functions. Mathematical reasoning tests are most frequently used as measures of General Reasoning (Ekstrom, French and Harman, 1976). When these consist of word problems they have some loading on the Verbal factor; and they, of course, are confounded with numerical ability. For this reason, General Reasoning is sometimes referred to as Quantitative Reasoning.

Relative to Induction as an ability, Ekstrom, French and Harman (1976, p. 79) state that "Induction appears to be a two-step process requiring both concept formation and hypothesis testing." Research has indicated that there are a number of sub-factors related to Induction, one of the most distinct of these being Figure Classification. Ross (1977) postulates two Induction factors - one verbally based (probably measured best by a Letter Series test) and one perceptually based, possibly related to the factor Flexibility of Perceptual Closure. In Guilford's structure of intellect model there are no less than 16 inductive abilities!

The factor originally called Deduction has more recently been referred to as Syllogistic Reasoning, Logical Reasoning and even Logical Evaluation. Tests of a syllogistic or inferential nature (drawing conclusions or making inferences from given premises) have always referenced this factor but such tests can share considerable variance "with verbal reasoning when the level of reading comprehension required is not minimized" (Ekstrom, French and Harman, 1976, p. 141). Two new essentially non-verbal tests to assess Logical Reasoning have been introduced by Ekstrom, French and Harman (1976). They are Diagramming Relationships and Deciphering Languages (see Appendix for examples).

TABLE 5

Reasoning Factors Associated with Selected Tests
in 13 Factor-Analytic Studies

TESTS	STUDY* 1	2	3	4	5	6	7	8	9	10	11	12	13
Arithmetic Reasoning		GR LR	GR	GR	GR		GR						GR
Necessary Arithmetic Operations	I					GR					GR	GR	
Ship Destination		GR	GR LR	GR	GR	GR	GR	GR	GR	GR	GR	GR	
Figure Classification	I	GR	I						I				I
Letter Series	I								GR I				I
Letter Sets									I		I	I	
Locations (Circles)	LR								I		I GR	I LR	
Verbal Analogies	I LR		I						I	I			
Inference		LR		LR			LR						
Logical Reasoning (Syllogisms)	I	LR	LR	LR		LR	LR	LR		LR GR	LR	I	LR
Nonsense Syllogisms (False Premises)	LR I	LR									LR GR	LR	

GR = General Reasoning (SI Model-CMS)
LR = Logical Reasoning (Deduction); (SI Model - EMR, EMI)
I = Induction (SI Model - CFC, CSR, CSC, CSS)

*1. Adkins and Lyerly, 1952.
2. Green, Guilford, Christensen and Comrey, 1953.
3. Guilford, Christensen, Kettner, Green and Hertzka, 1954.
4. Hertzka, Guilford, Christensen and Berger, 1954.
5. Wilson, Guilford, Christensen and Lewis, 1954.
6. Kettner, Guilford and Christensen, 1956.
7. Berger, Guilford and Christensen, 1957.
8. Frick, Christensen, Guilford and Merrifield, 1959.
9. Kettner, Guilford and Christensen, 1959.
10. Merrifield, Guilford, Christensen, Frick, 1962.
11. Lemke, Klausmeier and Harris, 1967.
12. Dunham and Bunderson, 1969.
13. Guilford and Hoepfner, 1971.

Summary and Conclusion

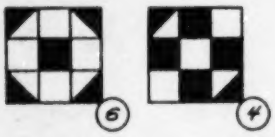
As stated at the beginning of this paper, reasoning is a complex and multi-faceted phenomenon, aspects of which are used in many diverse problem-solving situations. Probably no test can measure reasoning alone, since the test medium (verbal, symbolic, numerical, etc.) will intrude. Furthermore, if tests are made too simple, they may not measure reasoning ability at all.

Reasoning can be approached at different levels and with different degrees of analytic completeness (Adkins and Lyerly, 1952). Continuing exploration and research will undoubtedly clarify and consolidate some of the many different points of view (both psychological and philosophical) and definitions currently advanced in the domain of reasoning.

Appendix

Areas (Thurstone, 1938a, p. 42)

In each of the following figures, determine the total white area in terms of squares. The answers are shown in the attached circles.



Arithmetic Reasoning (Guilford and Lacey, 1947, p. 90)

The test consists of 30 arithmetic-reasoning problems. As examples of the test problems, an easy problem and a difficult problem follow.

If a plane is to fly 132 miles in 45 minutes, what must be its average speed?

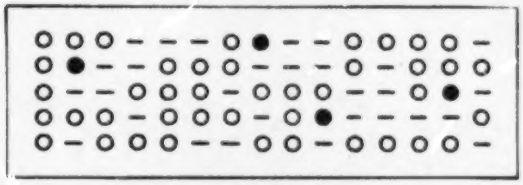
A. 146.7 m.p.h.
B. 164 m.p.h.
C. 165 m.p.h.
D. 176 m.p.h.
E. 182 m.p.h.

A plane traveled a certain distance from the base at an average rate of 225 miles per hour. Engine trouble forced it to return at an average rate of 150 miles per hour. It left at 11:35 and returned at 12:05 p.m. How far away from its base was the plane when it turned back?

A. 30 miles
B. 45 miles
C. 50 miles
D. 75 miles
E. 90 miles

Circles (Adkins and Lyerly, 1952, p. 26)

Figure out the rule and mark the circle in the bottom line that should be black.



Completion (Thurstone, 1938a, p. 28)

There is one word missing in each of the following sentences. The first letter of the missing word is shown in the parentheses.

A contest of speed is a ..... (r) race

In order to complete the sentence we have written the word race in the blank space. The two sentences below are completed correctly.

A fluid used in writing is.....(i) ink
A short sleep or doze is a.....(n) nap

Complete the following sentences in the same way. The word you use must begin with the letter shown in parentheses.

A person licensed to practice medicine is a ..... (d)_____
A cap used in sewing to protect the finger when pushing the needle is a..... (t)_____
The red fluid that circulates in the veins and arteries of man is..... (b) _____
The part of the day between noon and evening is.....(a)_____
A head covering is called a.....(h) (h)_____

Conclusions (Alkins and Lyerly, 1952, p. 26)

Each item contains from one to three sentences. The subject is to judge whether or not the conclusion follows from the rest of the argument, without regard for whether or not the argument is sensible.

Mark plus (+) for good arguments, minus (-) for bad arguments.

All wealthy men have automobiles, and he is wealthy. Therefore he must have an automobile.

Deciphering Languages (Ekstrom, French and Harman, 1976, p. 146).

For each different artificial language, three expressions in English and their translations into the language are given. From these you will need to figure out logically which syllable or which symbol in the language is equivalent to which English word. Note that the order of the symbols is consistent for any language, but may be different in each language and different from English. Therefore, do not assume that the first word in the artificial language refers to the first word in the English phrase, although sometimes it does.

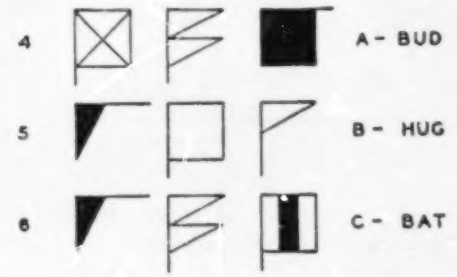
shaggy dog = ★ b
black cat = ■ m
black, shaggy cat = ■ ★ m

A. black dog =	B. shaggy cat =
1. ★ b	1. ■ m
2. ■ d	2. ★ m
3. ★ d	3. ■ d
4. ■ b	4. ★ d
5. ★ m	5. m ■

You should have marked 4. for sample A. and 2. for sample B.

Decoding (Guilford and Lacey, 1947, p. 100)

The test requires the decoding of short words written in a code of signal flags. The items are arranged in groups. In each group three to six rows of individual flag symbols are presented. Each symbol represents an unknown letter of the alphabet. They are arranged three or four to the row, and each row forms a commonplace English word when decoded. After examining the position of repeated flag symbols, it is possible to deduce the word that must correspond to each of the symbol lines.



Note that the letter b appears twice, each time at the beginning of a word. Since the symbol which appears at the beginning of two code words is a black pennant * * * this pennant must represent b. The letter u also occurs twice in these words, both times in the middle of a word. Thus the code symbol for u is the double white pennant * * * Since the first 2 symbols of item 6 are those which stand for b and u, this item must be bud. The other two items are solved by noting that item 5 begins with b and is therefore bat and that item 4 contains u as a middle letter and, therefore, must be hug * * *

Deductive Reasoning (Guilford and Lacey, 1947, p. 144)

An inspector general has an appointment in a city one hundred miles away. If the train on which he must travel is late, he will miss his appointment. If the train is not late, he will miss the train. We do not know whether the train is late. With this information, we can state positively that

A. He will not be able to keep his appointment.
B. He will be able to keep his appointment.
C. There is no way of telling whether he will be able to keep his appointment.
D. He will have to take a later train.
E. He will have to wait for the train.

Diagramming Relationships (Ekstrom, French and Harman, 1976, p. 144).

Each item in this test names three groups of things. You are to choose from the lettered diagrams at the top of the test pages the one diagram that shows the correct relationships among the three groups of things in each item. Mark the letter of the diagram that you select.

1. Animals, cats dogs

A B C D E

2. Desks, furniture, pencils

A B C D E

You should have marked A for 1 and E for 2.

False Premises (Thurstone, 1938a, p. 48)

This is a test of your ability to tell the difference between good and bad reasoning. You must judge only the reasoning in the following arguments because every statement is false or even absurd.

The first argument below is good reasoning and is marked plus (+). The second argument appears similar but is bad reasoning and is marked minus (-).

All haystacks are catfish. All catfish are typewriters. Therefore all haystacks are typewriters. +

All haystacks are typewriters. All catfish are typewriters. Therefore all haystacks are catfish. -

Figure Analogies (Guilford and Lacey, 1947, p. 105).

The Figure Analogies Test is designed to measure the ability to formulate correct logical relationships between sets of geometric figures. A test item presents the examinee first with three geometric figures labeled X, Y, and Z, which set the problem, and then with five alternate answers lettered A through E. Figure Y is always a simple variation of figure X. After ascertaining the relationship between the first two figures, the examinee selects from five alternatives the figure that bears the same relation to Z as Y did to X.

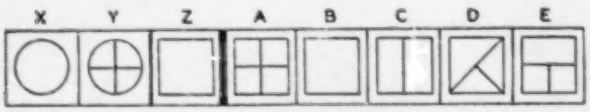


Figure Classification (Thurstone, 1938a, p. 25)

In each line below, there is a rule by which the symbols in Group I differ from those in Group II. There is a new rule for each line. Your problem is to discover the rule in each line. Some sample problems are worked for you below.

In the first line below the rule is that the symbols in Group I are horizontal while those in Group II are vertical. Each of the test symbols at the right belongs either to Group I or to Group II. The test symbols that belong to Group I have been checked.

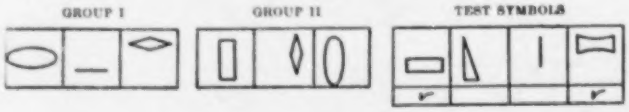
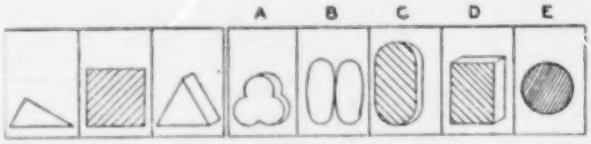


Figure Classification (Guilford and Lacey, 1947, p. 107

The examinee is to select from five alternatives the geometric figure that has the characteristic common to each of three figures that set the problem.

The three figures to the left of the heavy line, although of different shapes and sizes, are alike in one way. The lines which bound the figure are straight lines. Now examine the five figures labeled A, B, C, D, and E. Find the one figure which is bounded only by straight lines. The only figure which meets this requirement is figure D.



Inference (Guilford and Hoepfner, 1971, p. 414)

Choose one of five conclusions that follows from a factual, meaningful premise.

Sample premise: Most of the trees in the forest are green.
Alternative conclusions:

A. There are no yellow trees in the forest.
B. There are some yellow trees in the forest.
C. Some of the trees in the forest are green.
D. Green trees are the tallest in the forest.
E. Pine trees are green.

Answer: C.

Letter Grouping (Thurstone & Thurstone, 1941, p. 64)

Look at the groups of letters below.

AABC ACAD ACFH AACG

Three of the groups have two A's. The groups which does not have two A's is marked.

Letter Sets (Ekstrom, French and Harman, 1976, p. 81)

The examinee is presented with 5 sets of 4 letters and is to find the one set in which the relationship of the four letters does not fit the rule which characterizes the other 4 sets. The rules are not based on the sounds of sets of letters, the shapes of letters, or whether letter combinations form words or parts of words.

1. NOPQ (A) DEFL (B) ABCD (C) HIJK (D) UVWX (E)

Four of the sets of letters have letters in alphabetical order. The letters in set "B" are not in alphabetical order and therefore "B" is the correct answer -- i.e., the set which does not fit the rule.

Letter Series (Thurstone and Thurstone, 1941, p. 65)

Read the row of letters below.

a b a b a b a b _____

The next letter in this series would be a. Write the letter a in the blank at the right.

Locations (Ekstrom, French and Harman, 1976, p. 82)

In each problem there is a rule guiding the placement of the "x" in each of the first four rows. You are to figure out what that rule is and to use the rule in deciding where the "x" should come in row 5. When you you have picked the number in row 5 which appears where the "x" belongs, draw an X through it.

Example A:

Row 1 ---------- --x -----
Row 2 ----- --x-- ----------
Row 3 ---------- --x ------
Row 4 ----- --x---- ----------
Row 5 -------1-- --X--3-4 5---

Example A has been correctly marked. In the first four rows the "x" always replaces the third dash from the left of a group. The group is always the second group in the row. Therefore the correct answer is 2 because the number 2 replaces the third dash of the second group in row 5.

Necessary Arithmetic Operations (Arithmetic; Adkins and Lyerly, 1952, p. 22).

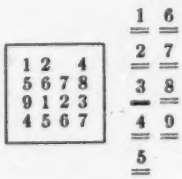
Check the answer which you think is right.

John had a dollar. He spent 80¢. To find out how much John had left, it is necessary to:

_____ add
__X__ subtract
_____ multiply
_____ divide

Number Patterns (Thurstone and Thurstone, 1941, 1941, p. 68)

Mark the number that is left out.



Number Series (Thurstone, 1938a, p. 46)

The numbers in each row of this test follow one another according to some rule. You are to find the rule and fill in the blanks to fit the rule.

19	18	17	_____	15	14	_____
8	11	14	_____	20	_____	
27	_____	23	23	19	19	_____

Number Series (Guilford and Lacey, 1947 p. 95)

Each problem in the test consists of an incomplete number series. It is the task of the examinee to determine by what rule of progression the series was constructed, and then to fill the gaps left in the progression with the missing numbers. Since two numbers are omitted in each progression, a problem contains two separately scored responses.

Sample Problems 1 and 2:

4 6 _____ 10 12 _____

(1)	(2)
A. 4	A. 10
B. 5	B. 14
C. 8	C. 15
D. 12	D. 16
E. 20	E. 18

The series above consists of numbers which increase by twos.

Numerical Judgment (Thurstone, 1938a, p. 46)

In this test you are shown some arithmetical problems that have already been worked out. Four answers are given for each problem. One of these is always the right answer. You are asked merely to check the right answer. You may use the space on the page for figuring but do not waste time working out the exact answer.

In the first problem below you can readily see that the first number is nearly 4 and the second number is nearly 7. Since 4x7=28, look for the answer that is nearest 28. This is the third answer and it is checked.

	7.563327	_____
4.12395 X 6.82187 =	14.012468	_____
	28.133051	✓
	56.103378	_____

Pattern Analogies (Thurstone, 1938a, p. 50)

Each problem in this test consists of eight figures. The first three are called A, B, and C. The next five are called 1, 2, 3, 4, and 5.

In Sample I below figure A is a large circle. Figure B is a small circle. By what rule is figure A changed in making figure B? The rule is "making it smaller." Apply this rule to figure C which is a large square. The result is a small square. Find the small square in the row of five figures at the right. It is figure 2. Therefore 2 is written in the blank at the right.

Sample I

A B C 1 2 3 4 5 2

In Sample III below the rule has two parts, "Make figure B larger than figure A and of the opposite color." If this rule is applied to figure C, the result is figure 1. Write 1 in the blank at the right.

Sample III

A B C 1 2 3 4 5 1

Reasoning (Thurstone and Thurstone, 1941, p. 75)

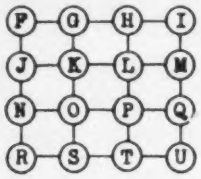
Read the "given facts' below and fill in the blank in the "conclusion."

Given Facts		Conclusion
M is larger than O O is larger than T	therefore	T is _____ than M

You should have written smaller in the blank.

Ship Destination (Guilford and Hoepfner, 1971, p. 473)

Find the distances from ships to ports, taking into account an increasing number of variables. The distance between neighboring positions is 2 miles.

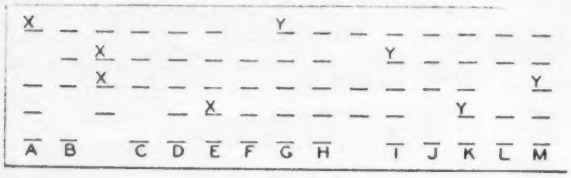


Sample variables: 1. Ship N to Port O
2. Ship J to Port G 3. Ship U to Port M

Answers: 1-2 miles; 2-4 miles; 3-4 miles.

Spatial Reasoning (Guilford and Lacey, 1947, p. 111)

The test requires the examinee to detect the principle governing the placement of letter symbols in a spatial pattern of dashes and gaps.



The rule for example 2 is, "The number of marks to the left of X increases by one in each row. Y is just to the right of the last gap in each row." X and Y are omitted from the last row, but according to the rule, X should be at the 5th mark (E) and Y should be at the mark following the last gap (I). Blacken spaces E and I after item 2 on your answer sheet.

Syllogisms Guilford and Lacey, 1947, p. 146)

Read each one of the following items as you come to it. Then decide whether the last sentence in each item necessarily follows if the preceding statements in the item are accepted as true. If you think that the last sentence is a necessary conclusion, make a mark in the corresponding space on your answer sheet lettered A. If you think that the last sentence is not a necessary conclusion, make a mark in the corresponding space on your answer sheet lettered B.

A sample item is: "Only thieves hide jewels. This man hid jewels. Therefore, he must be a thief."

Tabular Completion (Thurstone, 1938a, p. 44)

In the following table there are blank spaces. Fill in the correct numbers in these spaces. Get the necessary information from the rest of the table. Use the space below each table and on the opposite page for figuring.

Year	Marriages		Divorces		
	Number	Increase over Preceding Year	Number	Increase over Preceding Year	Number Granted to Husbar
1894.....	566,161	12,512	37,568	100	12,55
1895.....	598,855	32,694	40,387	2,819	
1896.....	613,873	15,018	42,937		14,448
1897.....	622,350			1,762	14,765
Total..	2,401,239	No total	165,591	No total	55,2

Verbal Analogies (Adkins and Lyerly, 1952, p. 52)

For each item, three words are given, and the subject chooses from among four additional words the one which bears the same relation to the third word as the second word does to the first.

Underline the word that completes the second pair.

SKY - BLUE :GRASS- earth green path blue

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